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Lisha Li

Iowa State University, lisa1107@iastate.edu

Dermot J. Hayes

Iowa State University, dhayes@iastate.edu

Chad Hart

Iowa State University, chart@iastate.edu

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Weather Adjusted Yield Trends for Corn: A Look at Iowa

Lisha Li, Dermot Hayes, and Chad Hart

lisa1107@iastate.edu; dhayes@iastate.edu; chart@iastate.edu

YIELD GROWTH in agricultural crops is of importance to those who make long-term projections of food availability and price levels. Menz and Pardey (1983) found that the trend growth in corn yields was lower in the 1970s than in the previous two decades. Tannura, Irwin, and Scott (2008) cited a number of crop experts and seed companies who believe that improved technology, particularly biotechnology, will increase the rate of yield growth in corn. Yu and Babcock (2010) found that percentage losses due to drought have been reduced over time, offsetting one of the major impediments to stronger yield growth. However, other researchers have argued that climate change will slow or even reverse the rate of yield growth (World Bank 2013).

The purpose of this report is to measure and present weather-adjusted trend yields for corn in Iowa. We use goodness-of-fit criteria to guide the choice of explanatory variables and the functional form of the relationship between yield and weather.

Our model controls for three key weather factors: rainfall, temperature, and the Palmer Drought Severity Index (PDSI). The PDSI is a long-term cumulative measure of water availability in the soil. The PDSI is negative if the soil is dry and positive when there is ample or surplus water. We control for linear and non-linear impacts of these variables and for interaction terms among them. Finally, we include a variable to measure the impact of heat stress. This is represented by the number of days when the temperature exceeded a certain critical value and is allowed to vary in each part of the state.

Data

Corn yield and weather data for all 99 counties in Iowa are sourced from the National Agriculture Statistics Service (NASS) for the years 1950–2012. County-level daily temperature data for each

July was collected from the National Oceanic and Atmospheric Administration (NOAA). The temperature data includes daily maximum temperature (TMAX). The number of days that maximum temperature exceeds each critical value ➡

Figure 1. Iowa Crop Reporting District (CRD) Map and Average Corn Suitability Ratings

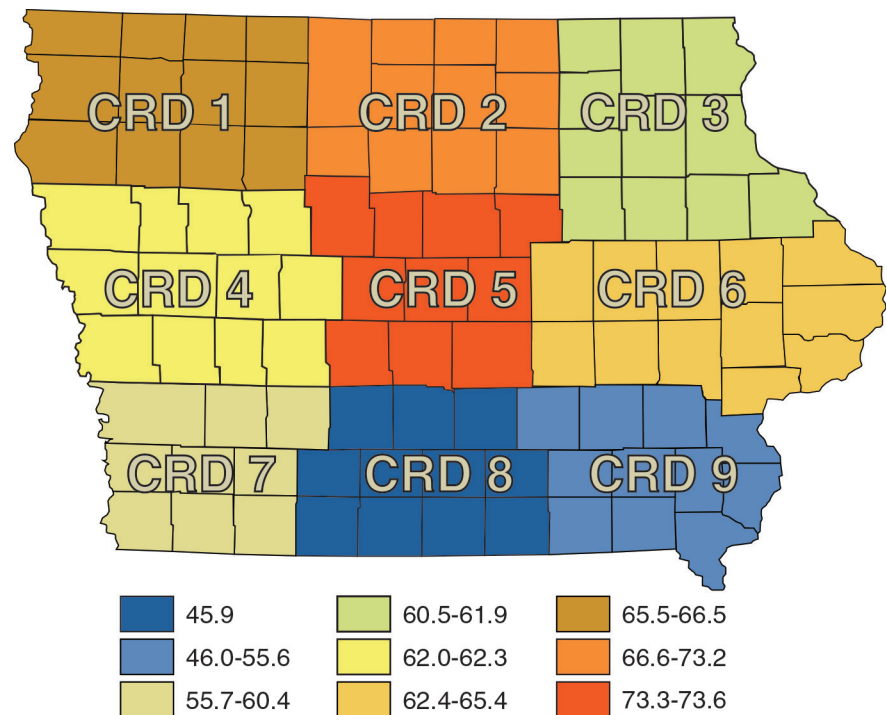
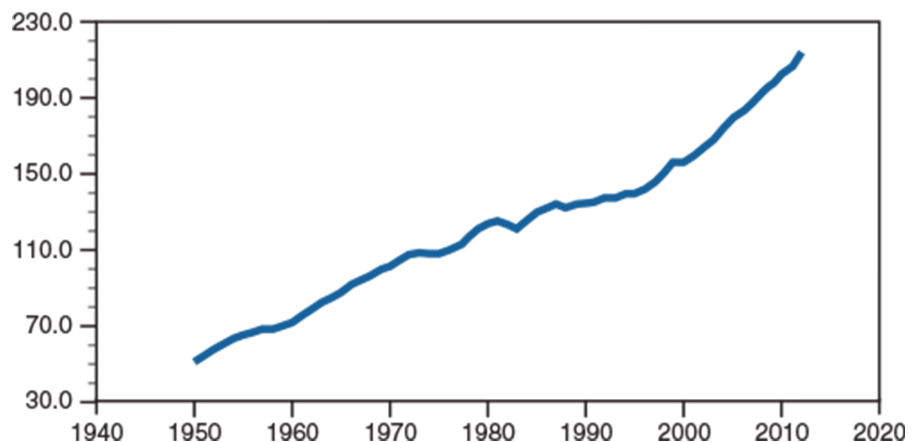


Figure 2. Statewide Results
Bushels per acre



is calculated from this daily temperature data. All the counties in the state of Iowa are matched with at least one weather station. For the counties with multiple stations, we use the average weather data for all stations included in the county. Where data is missing for one county in one year we use the weather data collected from neighboring counties.

The Palmer Drought Severity Index (PDSI) is available from NOAA at the Crop Reporting District (CRD) level. The 99 counties in Iowa are divided into nine CRDs. County-level total monthly precipitation (TPCP) data was also collected from NOAA. Total monthly rainfall for the period April to August is used to estimate the effect of rainfall on corn yield.

In order to prevent county-level anomalies as well as overly long tables, results presented here are for each of Iowa's nine crop reporting districts. The county-level results are very similar and available on request. The map of the CRDs in Iowa is presented in Figure 1. This figure also provides a measure of the suitability of the soils in each CRD to grow corn. CRDs 1, 2, 4, 5, and 6 have the higher quality soils for corn production, while CRDs 3, 7, 8, and 9 contain lower quality soils.

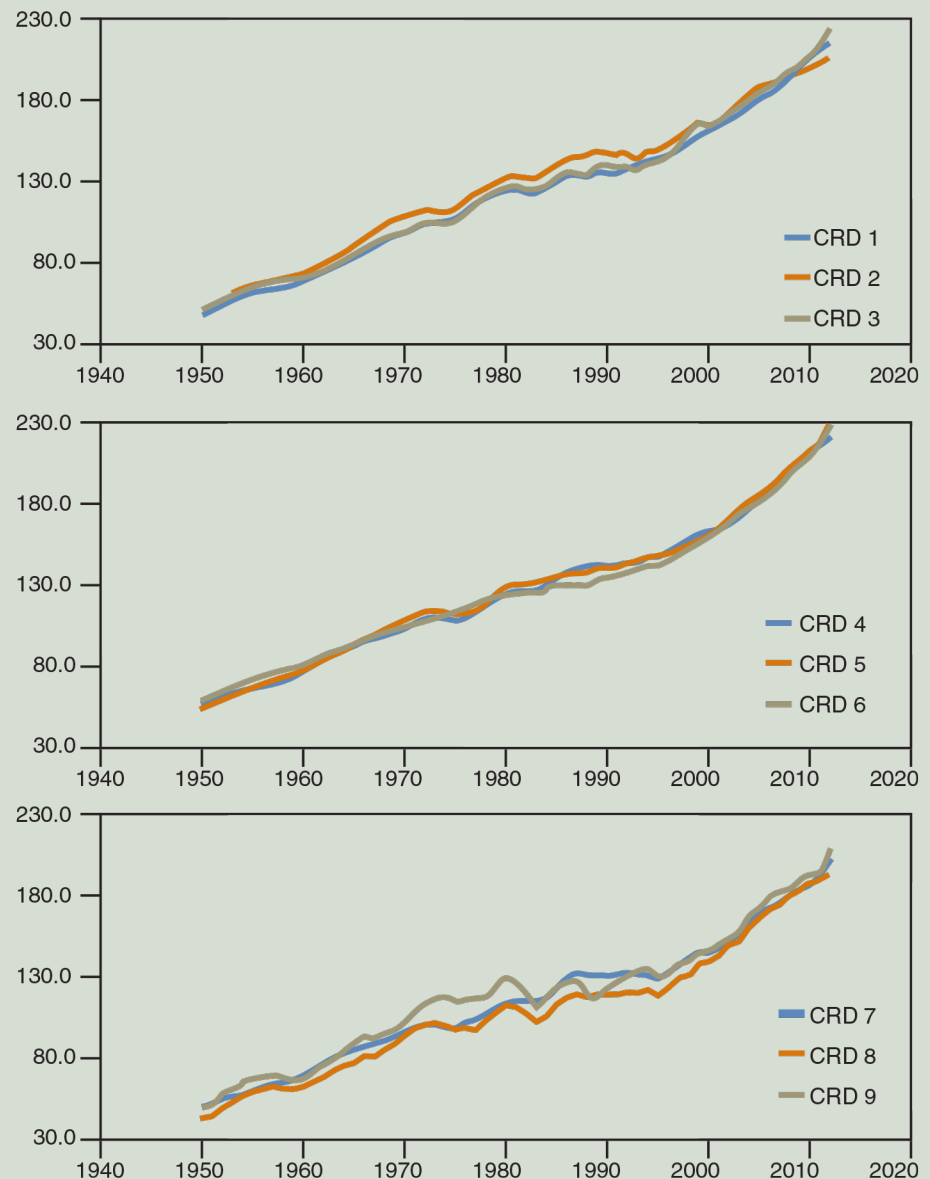
Results

Statewide results are shown in Figure 2. This shows that yield growth plateaued in the mid-1980s and then began to increase rapidly in the mid-1990s. The timing of the yield growth surge is consistent with, but does not prove, that insect resistant corn varieties, first commercialized in the mid-1990s, helped improve yields.

An example of this crop innovation is the corn-rootworm-resistant biotech trait (CRW), introduced in 2003. This technology has been widely adopted. It had a 20 percent market share in 2005 and a 50 percent share in 2011 (Marra, Piggott, and Goodwin 2012). This trait resulted in healthier, larger root systems

Figure 3. CRD Level Results

Bushels per acre



and had a significant yield impact in dryer areas that had been impacted by the pest. Rootworm problems were widespread in Iowa prior to the introduction of the trait (Marra, Piggott, and Goodwin 2012).

Figure 3 shows the regional trends in yield growth. These results show a consistent pattern across the regions in Iowa.

The yield growth we show here is due to genetic gain. Other variables such as disease, wind, management, and weather

impacts are not included in the trend estimates. In the exploration for the final model structure, our initial explanation for cross-CRD yield patterns was that there might be some excluded weather terms that explain patterns across the CRDs. We explored the possibility that an increase in excessively hot days occurred in the poorly performing regions, but this was not borne out by the results. We also examined whether there was an increase in the number of rain events with more than two inches of rain in one event.

Crop Insurance in Iowa

Alejandro Plastina and Chad Hart

plastina@iastate.edu; chart@iastate.edu

FARMERS ACROSS the nation rely heavily on crop insurance as a risk management tool—in Iowa alone over 93 percent of corn and soybean planted area was insured in 2014, but that participation rate hasn't always been the case. Participation in crop insurance declined substantially in the early 1990s after the mandate that required producers to purchase crop insurance in 1989 and 1990 to collect drought assistance in 1988 dissipated.

The fast recovery in 1994–1995 reflects the impact of higher effective subsidies rates and the requirement to obtain coverage in order to receive federal benefits instituted by the Federal Crop Insurance Reform Act of 1994. The 1996 Farm Bill repealed mandatory enrollment to receive federal benefits, but tied enrollment in crop insurance programs to disaster assistance instead. This resulted in a substantial drop in crop insurance participation between 1995 and 1997.

Despite another dip in effective subsidy rates between 1998 and 2000 as a result of changes in selected coverage levels, the percentage of planted acres participating in crop insurance has been trending upward since 1997 for both corn and soybeans.



USDA-ARS

The Agricultural Risk Protection Act of 2000 codified into law previously introduced ad hoc premium reductions (offered late in the signup period for 1998 and 1999) with a heavy focus on subsidizing more insurance plans with higher levels of coverage (O'Donoghue 2014).

Dominance of Revenue Products

Over the years, the menu of crop insurance policies expanded substantially by incorporating revenue

and area based products as well as more coverage levels. In order to simplify the analysis of participation decisions, we have classified all crop insurance programs into one of the following categories: farm catastrophic plans, farm yield buy-up plans, farm revenue buy-up plans, and county plans. Farm catastrophic (CAT) plans include the catastrophic options of Actual Production History (APH) and Yield Protection (YP) (the Group Risk Plan catastrophic plan is included under area plans in this analysis). Farm yield buy-up plans include those policies above the minimal, fully subsidized catastrophic coverage available to farmers from APH and YP. Farm revenue buy-up plans include Crop Revenue Coverage, Income Protection, Revenue Assurance, Revenue Protection, and Revenue Protection with Harvest Price Exclusion. County plans include both catastrophic and buy-up plans for yield and revenue coverage plans based on county data: Group Risk Income Protection, Group Risk Income Protection with Harvest Revenue Option, Group Risk Plan, Area Risk Protection, Area Risk Protection with Harvest Price Exclusion, and Area Yield Protection.

The evolution of the four insurance categories between 1989 and 2014

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Again, there was no statistically valid relationship. Our results indicate that there is some support for a higher yield growth rate in the northwest part of the state. This is the driest area in the state and therefore the corn rootworm trait may have been particularly beneficial.

The variable measuring the impact of extreme temperatures was not significant for CRDs 1, 2, and 4. However, critical temperature did emerge for other areas of the state. The critical temperature was 94 degrees for CRD 5, 95 degrees for CRD 6, 92 degrees for CRD 3, 93 degrees for CRD 9 and 90 degrees for CRDs 7 and 8. These results indicate

that the parts of the state with the highest CSR are best able to handle heat stress. One intuitive explanation is that corn growing on high quality soils may be able to resist high temperatures because the corn root system can source more water than in less productive soils. ■